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## COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE

### REPORT ON THE UNITED NATIONS INTERNATIONAL TRAINING COURSE ON REMOTE SENSING APPLICATIONS FOR ENVIRONMENTAL ASSESSMENT AND MONITORING, CO-SPONSORED AND HOSTED BY THE GOVERNMENT OF THE UNITED STATES OF AMERICA

(Sioux Falls, South Dakota, 9 September-4 October 1991)

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## INTRODUCTION

### A. Background

1. At its thirty-third session, in June 1990, the Committee on the Peaceful Uses of Outer Space endorsed the activities of the United Nations Programme on Space Applications for 1991 as proposed by the Expert on Space Applications and as recommended by its Scientific and Technical Subcommittee at its twenty-seventh session. Subsequently, the General Assembly, at its forty-fifth session, endorsed the activities of the Programme for 1991 (resolution 45/72 of 11 December 1990).
2. In response to resolution 45/72 and in accordance with the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82), the United Nations Outer Space Affairs Division organized an international training course on remote sensing applications for environmental assessment and monitoring.
3. The United Nations International Training Course on Remote Sensing Applications for Environmental Assessment and Monitoring, through the United States Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA), was organized in cooperation with the Government of the United States of America and hosted by USGS Earth Resource Observation System (EROS) Data Center for the benefit of Member States throughout the world.
4. The present report, which covers the background, objectives and organization of the training course as well as a summary of the lectures, has been prepared by the Outer Space Affairs Division in cooperation with the EROS Data Center for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. Participants in the course will report to the appropriate authorities in their respective countries.

### B. Organization of the course

5. Invitations to nominate candidates for the training course were sent by the co-sponsors to developing countries worldwide, and more than 200 applications were received. The co-sponsors jointly selected 23 participants and 2 observers from the following 25 countries: Argentina, Botswana, Bulgaria, Chile, China, Costa Rica, Côte d'Ivoire, Cyprus, Ecuador, Fiji, Gambia, Indonesia, Israel, Kenya, Malawi, Mexico, Mongolia, Nigeria, Peru, Philippines, Spain, Sri Lanka, Tunisia, Uganda and Venezuela.
6. The Government of the United States of America provided the cost of international air travel as well as the daily subsistence allowance for 23 participants.

7. The programme of the course (see the annex to the present report) was designed jointly by the United Nations Outer Space Affairs Division, USGS, NOAA and NASA. The United Nations was responsible for the overall external organization arrangements; the Government of the United States of America, through USGS, coordinated international travel as well as local arrangements and provided technical equipment, materials, course facilities and local transportation. In addition to knowledge gained through classroom and field study, participants were introduced to the life and culture of the United States, including an invitation to dinner by voluntary host families in Sioux Falls.

8. The course was opened by Dr. Donald T. Lauer of the EROS Data Center on behalf of the Government of the United States and Dr. Adigun A. Abiodun, United Nations Expert on Space Applications, on behalf of the United Nations.

## I. OVERVIEW OF THE COURSE

### A. Scope of the course

9. The course was designed to provide practical training in the processing and applications of satellite and other types of spatial data for environmental assessment and monitoring, with particular emphasis on land processes. The lectures included a review of the fundamentals of remote sensing and Geographic Information Systems (GIS) relating to practical uses of image processing techniques, laying stress on the actual operation of image processing systems as well as on participants' own initiatives for addressing various problems.

10. In order for the participants to undertake hands-on analysis operations using satellite images and GIS, they were provided with PC-compatible computers with CD-ROM readers and the GIS software "IDRISI" developed the Graduate School of Geography, Clark University, Worcester, Massachusetts. NOAA-AVHRR, LANDSAT-MSS/TM, SPOT and various geographic digital data were available for these exercises. A field trip was organized to perform in situ analyses and verify the results of the classroom analysis.

### B. Remote sensing fundamentals

11. Remote sensing technology is based on reflection or emission of electromagnetic energy from the surface of materials detected by the sensors. The information gained through this process varies in accordance with the electromagnetic spectrum because each material reflects incoming radiation or emits radiation based on its own spectral properties. Materials reflect or absorb incoming radiation at specific wavelengths; therefore, it is possible to detect materials by sensing such electromagnetic energy with specific sensors. Through this process, a material can be identified through its spectral characteristics. Materials of the Earth's surface differ in their response to energy of various wavelengths according to their chemical and

physical properties, configuration and so on. By analysing the reflections and emissions of these materials one can deduce the identity of a specific Earth surface.

12. Since the launch of Landsat-1 in 1972, space-based remote sensing has served as a very effective tool for land cover classification, ocean observation, geographic analysis and environmental monitoring. Various methods have been developed and tested for the practical uses of remote sensing satellites.

### C. Image processing

#### 1. Preprocessing

13. Prior to the practical applications of remote sensing data for various kinds of analysis, one needs to perform data calibrations and corrections and process the acquired digital data into images. Preprocessing is necessary in order to achieve image corrections to compensate for distortion. There are two categories of preprocessing or corrections: radiometric and geometric corrections.

14. Factors contributing to radiometric distortion include the following: (a) intermittent loss of data (transmission errors, synchronization loss, etc.); (b) noise (bit drops); (c) non-linear sensor response; (d) sensor miscalibration. Average adjacent lines, histogram normalization and noise filtering are examples of methods commonly used to achieve correction of radiometric distortions.

15. Geometric errors are introduced into observed data in three major ways: (a) systematic (aspects, non-linear mirror, etc.); (b) predictable (roll, pitch, yaw, altitude, etc.); (c) random (measurement error, relief displacements, etc.). Spatial location transformation, such as modelling distortions from spacecraft ephemeris and empirical approximation using ground control points and resampling are the methods used for the correction of these geometric errors.

#### 2. Image enhancement

16. To improve image interpretation, "enhancement" techniques are used which amplify positive spectral or spatial characteristics while suppressing non-essential characteristics or redundancy. Enhancement should be designed to improve imagery for specific interpretation purposes. It must be noted that improvement of the image for specific interpretation often makes interpretation of other features more difficult. Another important factor in enhancement is the characteristics of human "sense". For example, most people can detect more shades of green than shades of blue.

17. There are several categories of enhancement, e.g., contrast enhancement, spatial enhancement, arithmetic combination, spectral transformation. Each is usually undertaken for different purposes. For instance, to exaggerate the edges between contrasting cover types, a spatial enhancement method, which adjusts the brightness value of each pixel, may be taken in order to exaggerate the difference between a pixel and its neighbours.

### 3. Image classification

18. Multispectral classification is used for the reduction of data into desired information classes. This technique is based on the premise that each category of interest is spectrally unique. Classification includes the following four steps:

(a) Training: developing statistics that describe the spectral characteristics of the features to be classified; training the classifier to recognize spectral statistics;

(b) Classification: assigning multispectral pixels using the classifier into spectral categories based on training statistics;

(c) Spectral class labelling: assigning spectral categories to information classes;

(d) Post-classification refinement: resolving spectral confusion and other problems.

19. There are three types of training: supervised, unsupervised and a mixture of the two. Supervised training is done by individual measurement of the multispectral characteristics of each class of interest, while unsupervised training is executed automatically using random or systematic methods. These three methods differ with respect to cost and accuracy.

### 4. Output devices

20. Three types of output devices are used for images or map-type products, namely, vector pen plotters, colour raster inkjet or electrostatic plotters and printing/raster film plotters. Owing to the need to produce high-volume raster data, various kinds of raster plotters are in use and are being developed, such as laser printers, inkjet and electrostatic printers. Since each printer has advantages and disadvantages, users should compare the features of these printers and select the one most suitable for their particular purposes.

#### D. Geographic Information System

21. The Geographic Information System (GIS) can be defined as "a system for entering, storing, retrieving and updating spatial information for a user's area of interest, designed to process information on demand and to present results in a format most suitable for the user's application". It consists of databases (e.g., geologic and vegetation information, climatic data, administrative data), hardware and software, and its basic function is to create outputs through manipulation of input data. Digital maps, remote sensing images and results of various analysis are typical for a database. Hardware often includes an input device such as a scanner, a processing computer and an output device such as a printer.

22. The advantages of GIS include the following: flexibility (analysis, evaluation, revision, updating); timeliness; potential for rapid analysis and dissemination; consistency; potential for significant enhancement; secure data for future use.

#### E. Example of applications of remote sensing and GIS

23. Remote sensing technology and GIS are applied in various fields. Satellites can provide data of a wide area; it is almost impossible for this to be done by a ground station network. The ability of satellites to observe the Earth globally, repeatedly and with the same instruments is of crucial value for environmental monitoring and assessment. The following examples of applications were discussed in the course.

24. United States AVHRR dataset. A dataset was developed for the conterminous United States containing 1 km AVHRR and greenness data for biweekly composites through the 1990 growing season. The data were made available on CD-ROM and were used throughout the course.

25. Topographic and hydrologic applications. Software was created to extract topographic structure and delineate watersheds and overland flow paths from digital elevation models (DEM). DEM were integrated with flow direction and flow accumulation data sets in the GIS database.

26. Greenness mapping in Africa. For the monitoring of site-specific dynamic vegetation conditions associated with grasshopper and locust breeding, vegetation index data obtained by NOAA satellites were integrated in a GIS with digital cartographic data of individual countries to provide near real-time image maps in the late 1980s.

27. Operational environmental satellite remote sensing for food security and locust control. For real/near real-time precipitation and vegetation assessment in Africa, the Near East and South-West Asia, an operational satellite environmental monitoring system, ARTEMIS, was implemented by the Food and Agriculture Organization of the United Nations (FAO), in cooperation with the NASA Goddard Space Flight Center, the National Aerospace Laboratory

of the Netherlands and the universities of Reading and Bristol. The system utilizes integrated high-frequency Meteosat data and NOAA AVHRR data. A satellite telecommunication system called DIANA is being developed by the European Space Agency (ESA) in cooperation with FAO; this would permit near real-time transmission of high-volume ARTEMIS digital data products to microcomputer-based terminals.

28. Participants were also introduced to the meteorological application of remote sensing, including an actual and accurate weather forecast for their field trip.

#### F. Team projects

29. All the participants were divided into six groups, each consisting of experts in different areas; the groups were thus basically multidisciplinary teams. Each was provided with a personal computer and satellite images. On the basis of the interests of its members, every group selected a problem it would address in the Black Hills area of South Dakota and worked on that problem using GIS, satellite images and a personal computer. Team projects were organized to maximize participants' initiative; these projects included practical uses of GIS, remote sensing imageries and the field trip for gathering ground truth for subsequent verification.

##### 1. Themes of team projects

30. The themes of the team projects were the following:

Group 1: assessment of relations between geology, slope and land use in the Spearfish area using LANDSAT TM images;

Group 2: study of the seasonal vegetation types in South Dakota using the Normalized Difference Vegetation Index (NDVI) computed from AVHRR data;

Group 3: Rapid City land use update;

Group 4: land use mapping of Rapid City;

Group 5: revision of the land use classification of Spearfish using recent LANDSAT TM data;

Group 6: vegetation/rock discrimination using TM images in the Rapid City area.

## 2. Field trip

31. The participants went on a five-day field trip around the Black Hills, in the most eastern extension of the Rocky Mountains, in order to collect in situ data for the analysis and verification of the team projects. During the field trip, the participants were introduced to various kinds of geologic, geographic and vegetation features as well as human activities in the area, along with satellite images and GIS outputs.

32. The Black Hills constitute one of the oldest regions of the North American continent and are a classic example of "up-doming" mountain formation. A complete sequence of rock strata is found around the Hills and the area is of great geological significance. It covers nearly 6,000 square miles and rises about 3,000 to 4,000 feet above the surrounding plains, with the highest peak standing at 7,242 feet above sea level.

33. Four vegetational complexes are prominent in the Black Hills: a Rocky Mountain coniferous forest complex dominated by ponderosa pine; a northern coniferous forest complex consisting of white spruce; the grassland complex of the northern Great Plains; and a deciduous forest complex. The participants surveyed these complexes and compared their respective features on the satellite images of the area. A major forest fire had occurred in the south-eastern part of the Black Hills three years earlier and had burnt an area of almost 200 sq km. Changes in the vegetation caused by the fire were shown to the participants in situ, in comparison with satellite images of the area.

34. Participants also visited the Badlands, a rugged, eroded terrain dissected by numerous gullies and arroyos. The distinctive features of the Badlands are easily located on satellite images.

## 3. Experience in team projects

35. After the field trip, teams worked on finishing their studies by combining classroom work and their experience from the field trip. Each team was given 30 minutes to present its work to the other participants and instructors and discuss the results. Through their work on team projects the participants experienced a multidisciplinary approach to solving problems and gained knowledge in the practical use of image analysis based upon their own initiatives.

## II. EVALUATION OF THE TRAINING COURSE

36. At the conclusion of the course, the participants were asked to complete a questionnaire on the various aspects of the content and organization of the course, including the time allotted to the topics and practical hands-on exercises of digital processing as well as the level of the subjects covered.

37. The participants expressed the opinion that the general organization and the planning of the presentations were of high quality. Depending on their experience and field of expertise, participants felt that certain topics should have been presented in greater detail. As a whole, and based on the variety of the expertise among the participants, many of them expressed the opinion that the basic fundamentals of remote sensing, digital data processing and GIS should be discussed further. It was also pointed out that the practical exercises and the field trip to evaluate the analysis was indispensable for this kind of training and it would have been more effective if there had been more computers and time allocated for that purpose.

38. The participants were unanimous in expressing their appreciation to the Government of the United States of America and to the United Nations for having organized the course. In particular, the participants highly appreciated the hospitality and devotion of the staff of the EROS Data Center. The participants also expressed their strong desire that this kind of training course should be continued.

39. The quality of the participants and their eagerness to obtain further knowledge of remote sensing, combined with the sincere effort of the instructors, contributed to the success of the course. The participants appealed to the United Nations to continue to provide this kind of training opportunity and to explore the possibility of a continuous long-term education programme in this rapidly advancing technology.

Annex  
PROGRAMME OF THE COURSE

| <u>Date</u>                | <u>Time</u> | <u>Subject</u>                                                                                                                                            | <u>Speaker</u>                                                     |
|----------------------------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|
| Monday,<br>9 September     | 9-11 a.m.   | Welcome                                                                                                                                                   | Adigun A. Abiodun<br>(United Nations)<br>Donald T. Lauer<br>(USGS) |
|                            | 1-4.30 p.m. | Review of remote sensing fundamentals<br>Electromagnetic spectrum<br>Present and proposed sensors                                                         | C. Trautwein (USGS)                                                |
| Tuesday,<br>10 September   | 9 a.m.-noon | Fundamentals of image processing<br>Digital image characteristics<br>Geometric and radiometric corrections<br>Image processing                            | C. Trautwein                                                       |
|                            | 1-4.30 p.m. | Tour of EROS Data Center                                                                                                                                  | C. Trautwein                                                       |
| Wednesday,<br>11 September | 8-11 a.m.   | Introduction to digital processing<br>Overview of hardware/software<br>Introduction to PCs<br>Digital databases available<br>Local and wide-area networks | D. Greenlee (USGS)<br>D. Greenlee<br>F. Waltz (USGS)<br>F. Waltz   |
|                            | 1-4.30 p.m. | Introduction to Black Hills Database<br>(form teams)                                                                                                      | J. Pursall (USGS)                                                  |
| Thursday,<br>12 September  | 8-11 a.m.   | Image enhancement<br>Spectral (e.g., contrast enhance)<br>Spatial (e.g., edge enhance)                                                                    | D. Greenlee                                                        |
|                            | 1-4.30 p.m. | Spectral transforms<br>Band ratios, principal components                                                                                                  | C. Trautwein                                                       |
| Friday,<br>13 September    | 8-11 a.m.   | Digital image classification<br>Decision rules<br>Supervised/unsupervised<br>Development of training statistics<br>Post-classification refinement         | D. Ohlen (USGS)<br><br>D. Ohlen<br>D. Ohlen                        |
|                            | 1-4.30 p.m. | Exercise (Black Hills data)                                                                                                                               |                                                                    |
| Monday,<br>16 September    | 9 a.m.-noon | Temporal analysis<br>Composing process<br>Change detection                                                                                                | J. Eidenshink (USGS)<br>G. Tappan (USGS)                           |
|                            | 1-4.30 p.m. | Applications case-studies<br>Conterminous United States AVHRR Dataset<br>Greenness mapping in Africa                                                      | J. Eidenshink<br>G. Tappan                                         |

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| <u>Date</u>                | <u>Time</u>   | <u>Subject</u>                                                                                       | <u>Speaker</u>       |
|----------------------------|---------------|------------------------------------------------------------------------------------------------------|----------------------|
| Tuesday,<br>17 September   | 8-11 a.m.     | Applications case-studies<br>Normalized Difference Vegetation<br>Index (NDVI) for fire fuels mapping | J. Eidenshink        |
|                            | 1-4.30 p.m.   | Temporal analysis exercise                                                                           | J. Eidenshink        |
| Wednesday,<br>18 September | 8-11 a.m.     | Introduction to Geographic Information<br>Systems (GIS)                                              | N. Bliss (USGS)      |
|                            | 1-3 p.m.      | Spatial analysis techniques                                                                          | N. Bliss             |
|                            | 3-4.30 p.m.   | Applications case-studies<br>Soils Database (NATSGO/STATSGO)                                         | N. Bliss             |
| Thursday,<br>19 September  | 8-11 a.m.     | Topographic analysis<br>Derive slope, aspect, shaded relief<br>Extract basins and drainage           | S. Jenson (USGS)     |
|                            | 1-2 p.m.      | Applications case-studies<br>Hydrologic applications                                                 | S. Jenson            |
|                            | 2-4.30 p.m.   | Topographic analysis exercise                                                                        | S. Jenson            |
| Friday,<br>20 September    | 8-11 a.m.     | NGDC global diskette project                                                                         | J. Kineman (NOAA)    |
|                            | 1-4.30 p.m.   | Climatology applications<br>Hydrologic, marine and atmospheric<br>applications                       | K. Gallo (NOAA)      |
| Monday,<br>23 September    | 8-11 a.m.     | Output products and data presentation                                                                | J. Hutchinson (USGS) |
|                            | 1-4.30 p.m.   | Demonstration                                                                                        | J. Hutchinson        |
| Tuesday,<br>24 September   | 8-11 a.m.     | Team projects - work on PC datasets                                                                  | Staff                |
|                            | 1-4.30 p.m.   | Work on PC datasets                                                                                  | Staff                |
| Wednesday,<br>25 September | 8-11 a.m.     | Work on PC datasets                                                                                  | Staff                |
|                            | 1-3.30 p.m.   | Work on PC datasets                                                                                  | Staff                |
| Thursday,<br>26 September  | 8-10 a.m.     | Work on PC datasets                                                                                  | Staff                |
|                            | 10 a.m.-noon  | National Weather Service briefing                                                                    | G. Harmon (NOAA)     |
| Friday,<br>27 September    | 8 a.m.-6 p.m. | Field trip (Badlands National Park)                                                                  | Staff                |

| <u>Date</u>               | <u>Time</u>   | <u>Subject</u>                                                                                                               | <u>Speaker</u>       |
|---------------------------|---------------|------------------------------------------------------------------------------------------------------------------------------|----------------------|
| Saturday,<br>28 September | 8 a.m.-6 p.m. | Field trip (Black Hills National Park)                                                                                       | Staff                |
| Sunday,<br>29 September   | 8 a.m.-6 p.m. | Field trip (Black Hills National Park)                                                                                       | Staff                |
| Monday,<br>30 September   | 8 a.m.-6 p.m. | Field trip (Black Hills National Park)                                                                                       | Staff                |
| Tuesday,<br>1 October     | 8 a.m.-4 p.m. | Field trip (return to Sioux Falls)                                                                                           | Staff                |
| Wednesday,<br>2 October   | 8 a.m.-noon   | Preparation of student presentations                                                                                         | Staff                |
|                           | 1-4 p.m.      | Student presentations and discussion                                                                                         | Staff                |
| Thursday,<br>3 October    | 9-11 a.m.     | Operational environmental satellite remote sensing and information dissemination for food security and locust control by FAO | Jelle Hielkema (FAO) |
| Friday,<br>4 October      | 9-11 a.m.     | Closing ceremony                                                                                                             |                      |

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